Advanced Order Planning in Networked Enterprises

A. Azevedo[1,2], C. Toscano[2] and J.P. Sousa[1,2]
[1]Faculdade de Engenharia da Universidade do Porto - Rua Roberto Frias, 4200-465 Porto, Portugal
[2]INESC Porto - Rua Roberto Frias, 4200-465 Porto, Portugal

Abstract
This paper describes an order planning system for dynamic networked enterprises, addressing the requirements of a make-to-order business environment. A distributed and decentralised information system, based on an architecture of agents and extensively using the internet, was designed and implemented in order to provide new and more powerful decision support concerning order management across each node of the network. The system aims at responding to the basic requirements of cooperativeness, integration and configurability in business networking environments. It was developed under the scope of the Co-Operate European Project, and implements the functionality of a general order promising process viewed as a distributed business process.

Keywords:
Distributed Enterprises, Decision Support Systems, Multi-Agent Systems

1 INTRODUCTION

A key factor for the success and survival of an enterprise is its ability to quickly react to changes taking place in today's global and competitive environments. World-wide availability, quick response to market needs, flexibility of production and delivery reliability of raw materials and finished products are some of the challenges that companies operating in a global economy are facing. Competitive advantage, gained by the reinforcement of core competencies, is leading many companies to establish temporary networks of business partners, thus creating supply chains or networks.

In very complex and dynamic environments such as the automotive and semiconductor industries, the task of managing and coordinating the procurement of materials, the transformation of these materials into intermediate and finished products, and their distribution to the customer is very complex and quite demanding in terms of information support.

The need to dynamically manage complex supply chain networks implies fundamental changes in the design of information systems with regard to planning and co-ordination activities [1].

In fact, co-operative networks of companies can be made up of many different entities and various types of interaction between the participating entities may take place. Their co-ordination and the access and sharing of knowledge and information are becoming increasingly important. Moreover, setting up the network and managing it in an optimised way, balancing customer needs with increased performance along the whole network, may be a key factor for the competitiveness of a company. In particular, a lot of attention should be given to the design of effective methodologies and tools to support co-operation and collaboration, as applied to processes such as aggregate planning and customer order negotiation.

Currently available systems claim to support the issues arising in networked organisations. However, it is widely recognised they still have important gaps, and therefore this paper proposes a new concept for the design of a distributed Information System, that responds to the basic requirements of co-operativeness, integration and configurability.

The present research work is the outcome of an European Community IST project, called Co-Operate [2]. A system prototype is being evaluated in specific automotive and semiconductor pilot companies, which are part of rather complex and dynamic production networks. This prototype is able to plan order requests across the entire production network using capacity feasibility checking through local capacity models.

The paper is organised as follows. In the next section the general approach and solution considered in the scope of the research project Co-Operate is presented. The architecture of a Decision Support System (DSS) for co-operative planning in networked supply-chains is then described. Finally, some concluding remarks and current developments are presented.

2 GENERAL APPROACH

2.1 Business Solutions

Our research has shown that traditional enterprise information systems do not suitably cope with some new demanding requirements of a distributed and heterogeneous manufacturing environment. In particular, for order negotiation and planning, we need:

- support for decision autonomy and proactiveness besides basic decision making functionality;
- new communication and expression paradigms to help the implementation of delegation and co-ordination;
- new planning methodologies based on negotiation and in co-operation strategies;
- intelligent functionality integrated into management applications.

To tackle these issues, the Co-Operate project identified a set of requirements related to business processes taking place pairs of adjacent nodes of a business networking environment. In order to effectively respond to the general requirements stated above, a set of distributed business processes were identified that have been validated by the companies in the project and will hopefully be easily extended to other industries.

These "business solutions" have been defined taking into account the network aspects of the processes and trying to accommodate and support the current internal tools and processes of the companies.

A brief description of some business solutions follows.

Long term business planning for the network

The goal is to generate long-term plans for the network by synchronising forecasts and plans, and by promoting early communication of changes and feedback about feasibility.

Standard operational order and planning process

This includes order generation and transmission, synchronised planning, monitoring and status information. It should provide a strong basis for real-time order promising and exceptions handling.

Request feasibility studies for new order or change requests across the network

To support and co-ordinate the feasibility checks at the individual companies within the shortest possible time. This includes checking of capacity and materials from suppliers.

Exception handling process.

Includes methodologies to detect, as early as possible, problems in the network such as peak orders, capacity shortages or part availability problems.

2.2 The ReFS Business Solution

The business solution "Request feasibility studies for new order or change requests across the network" (ReFS) supports the order promising business process across the network. Its main objective is to provide a fast response to incoming new orders (order promising) or to accommodate requests for large order changes, which exceed the current availability allocation. When a request enters the enterprise network at a given node, its feasibility is checked internally taking into account the capacities and plans of the node, and externally by forwarding the request to the next relevant nodes (suppliers in the supply-network). The final answer to the customer is then fed back to the node where the initial request had occurred.

A number of "what if" questions related to the satisfaction of a customer request may be answered by the system. The following are examples of such questions:

- what quantity of a given product can be delivered to the customer by the requested due date?
- on what date could the entire request be satisfied?
- what additional resources would be needed to fully satisfy the customer's request?

For the general functionality of ReFS (order promising process), we consider one scenario that assumes that a core company, having their own customers downstream in the chain, is a customer for a given number of suppliers. The suppliers can request an updating of orders either by a pull or push process.

We identify four kinds of actors: the customer of the core company, the expeditor at the core company, the supplier and the enterprise information systems (typically an ERP system) of the core company. The following main tasks have also been identified:

Order transmission

Allows to automatically send information to all suppliers using the best communication channel; all orders from the core company to each supplier are displayed together with their actual status; the supplier can view them sorted according to a customisable filter; all new and changed orders (which have not yet been acknowledged by the supplier) are highlighted.

Acknowledgement of orders

The planner of the supplier can acknowledge each new or changed order and automatically the system registers the acknowledgement data such as date/time, user identification, etc; all changes are stored in a log table.

Order request

This task deals with the feasibility of new incoming orders, producing a quotation, with a real-time check of capacity and materials availability; this task supports and co-ordinates the feasibility checks at the individual companies within the shortest possible time including checking for own capacities and requesting needed materials from suppliers; these will propagate the process to their own suppliers.

Track Order

Basically this unit of functionality allows an end-customer or a supplier, to track, along the production chain, the position and the status of each related order.

In order to satisfy the requirements stated for this business solution, the response to customer inquiries should be given in useful time, and the scheduling of large order changes should be reliable and be consistent with the other supply network processes. The focus of this particular process is on situations in which the reaction time frame allows regular operational changes and adaptations, as opposed to emergency handling.

The set of requirements identified and in particular the heterogeneous, dynamic and networked features of main business processes led us naturally to explore the benefits of a distributed approach, based on a framework of multiple agents that communicate through 'speech acts' of advanced languages. Multi-agent systems, seem to be well suited to model dynamic networks of enterprises, as they naturally provide a set of features that make the implementation and the operation of complex distributed systems easier [3].

3 A MULTI-AGENT BASED ARCHITECTURE

3.1 Basic principles

A distributed architecture based on agent technology and extensively using the Internet was designed. Basically, the networked supply-chain is modelled as a distributed system, without any central coordination of activities.

The architecture is structured around the following basic architectural principles:

- each business unit in the network of companies is served by a set of agents;
- each of these sets is a 'node' in a community of agents distributed by the several 'business units' in the network;
- in each node, the agents co-operate to achieve local goals;
- in each node, each agent performs one or more functions, and co-ordinates its decisions with the other agents in the node;

- in each node, the users playing the role of planner or configurator are in total control of the scope of the decisions made by planner and capacity agents;
- different nodes in the network co-operate to achieve global or local network goals - co-operation between nodes is carried out through the interactions of the individual agents in the different nodes;
- the functionality across the network is achieved through the interaction of the different nodes;
- the types of agents in each node are variable, depending on its required functionality.

Some of the agents in a node have external visibility, thus interacting with agents in the other nodes of the network, whilst some agents have a local scope, being limited to accomplish local goals. Agents belonging to different nodes and carrying out direct conversations between each other, give support to the global network planning procedures.

In order to support the negotiation dialogs between agents (representing each business unit in the network), we have considered some specific organisational agents, referred to here as communication facilitators, or simply as facilitators. These agents provide communication services such as registering or localising agents according to their expressions of interest or knowledge, forwarding messages, routing messages based on their content, and providing mediation and translation services. Facilitators do not directly carry out any operational function in the enterprise network. A two-level hierarchy of facilitator agents mediates and co-ordinates local interactions (between the agents located in a given node) and network interactions (between agents located in different nodes in the network).

The structure of the network is dynamic: nodes may be inserted into or deleted from the network during a re-configuration process. This set-up is accomplished through registration dialogs between each local agent and one or more facilitator agents. Registration actions create a network of agents that will then be organised or configured according to the specific features of the network under creation.

According to the basic strategy defined by the project, there can only be direct communication of information between companies with direct customer-supplier business relationships.

3.2 Protocols and conversations

The interaction between the several software agents forming the multi-agent system of a given network of companies, was implemented according to the rules defined by the standardisation work of FIPA - the Foundation for Intelligent Physical Agents [4],[5]. Accordingly, a conversation is an ongoing sequence of communicative acts exchanged between two or more agents relating to some ongoing topic of discourse. As such, a protocol is defined as a set of conversations, which exhibit typical patterns of message exchange.

The RefsAgent implements the FIPA-request protocol. Figure 1 presents the related UML (Unified Modelling Language) sequence diagram.

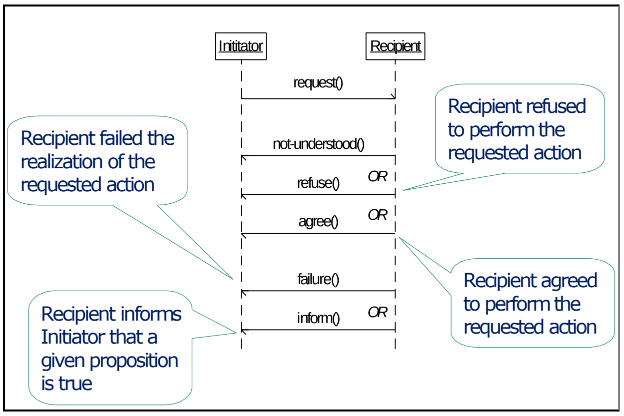

Figure 1: FIPA-request protocol

The Initiator entity corresponds to the RefsAgent that initiates the conversation and the Recipient entity corresponds to the destination RefsAgent (in a one-to-one connection). The protocol is instantiated twice, in order to implement the following two types of conversation between any two RefsAgents:

- query the ATP (Available-to-Promise) and the CTP (Capable-to-Promise) information;
- check the feasibility of a new order request.

ATP and CTP information query

The protocol is instantiated by any RefsAgent in situations where the ATP and CTP information is required from the direct suppliers of the company represented by that RefsAgent. The input to the protocol is composed by three items:

- SupplierID: identification of the RefsAgent that is the target of the inquiry process;
- ProductID: reference code of the product supplied by the target company and for which ATP and CTP information is required;
- DeliveryWeek: identification of the delivery week for which ATP and CTP information is required.

In normal situations, the reception of a “request” message triggers the transmission of an “agree” message (Figure 1). Calculation of the ATP and CTP values for the product referred by “productID” and for the week referred by “DeliveryWeek” is then accomplished.

Feasibility checking of new order requests

The protocol is instantiated by any RefsAgent in situations where the feasibility of a new order request is required to be analysed. The recipients of this type of conversation can only be the companies that act as direct suppliers of the company represented by the RefsAgent initiating the conversation.

The following items are the input of the instantiation of the protocol:

- SupplierID: identification of the RefsAgent that is the target of the inquiry process;
- ProductID: reference code of the product supplied by the target company and for which the feasibility of a new order request is demanded;
- Quantity: number of units of the product referred by productID;
- DeliveryWeek: due date of the order request.

The reception of a “request” message by a RefsAgent triggers its internal analysis process, eventually resulting in the transmission of an “agree” message (if the agent agrees to analyse the request), followed by an "inform" message, describing the result of the inquiry process.

3.3 Internal Organisation

The internal organisation of the RefsAgent is represented in Figure 2 (UML component diagram).

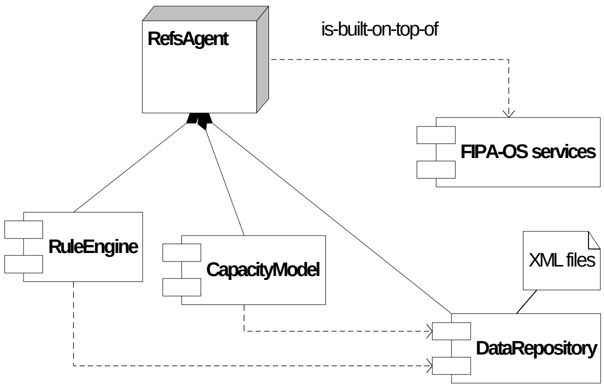

Figure 2 – RefsAgent internal organisation

The FIPA-OS-services component represents the whole set of services provided by the FIPA-OpenSource (FIPA-OS) framework which forms a reference implementation of the FIPA open standards for agent interoperability [6]. This framework, available in the Java computational platform, provides support for:

- different types of agent shells for producing agents, which can then communicate with each other using the FIPA-OS services;
- multi-layered support for agent communication;
- message and conversation management;
- dynamic platform configuration, multiple types of persistence and multiple encodings;
- abstract interfaces and software design patterns;
- diagnostic and visualisation tools.

The RuleEngine component gives the RefsAgent the ability to "reason" using knowledge supplied in the form of declarative rules and heuristics. Decision making to support internal processes is accomplished via this inference mechanism. A third-party tool, the Jess rules engine, implements this component. Basically, Jess supports the development of rule-based expert systems that can be tightly coupled to code written in Java. The different rules and heuristics defined by the human user are kept in an XML file inside the DataRepository component.

Data persistency of the whole RefsAgent is assured by the DataRepository component, through a set of XML files. Additionally, these XML files act as the interface between the RefsAgent and the available legacy systems within the company. Interactions between instances of a RefsAgent and each legacy system are accomplished through the periodic exchange of XML-based data.

3.4 Capacity Model

ReFS deals with rather aggregate information adequate for global planning of the whole supply network. In this context, the Capacity Model component provides ReFS with a measure of the production unit capacity, supports the creation of medium-long term plans, performs material management, and evaluates the local implications of a given customer order.

Several key concepts form the basic elements of a Capacity Model:

- Meta-Product - Group of products with similar characteristics in what concerns their production processes.
- Macro-Operation - A concept aggregating several sequential operations with similar characteristics. A macro-operation is a high level conceptual operation that encompasses a set of real production operations.
- Resource-Centre - Aggregation of a set of shop floor work-centres. It represents the bounding resource capacity for a specific macro-operation.
- Production-Routing - The sequential set of macro-operations that have to be carried out in order to manufacture a single meta-product.

To each resource-centre an effective (probably not constant) capacity along the planning horizon is associated.

The construction of an aggregate data model describing the production process of a set of products, involves two main actors in each network node: a human planner and the company's own planning system (e.g. Enterprise Resource Planning). This process is performed through a specific component (user interface agent).

4 CONCLUSIONS

The system presented in this paper has been installed and tested in three main nodes of a dynamic supply-network involving different sectors. Concerning the ReFS business solution, a real-time customer order planning functionality is available for each enterprise node of the supply-network, improving the global response time for new order requests and enhancing order promising. Furthermore, the developed solution leads to better management of the actual production capacity along the whole supply-network.

Although preliminary experience has clearly proved the potential of this approach, the growing importance of this subject justifies further work. We intend therefore to explore this line of research, namely in understanding the mechanisms of decision-making for networked enterprises and in developing collaborative and negotiation procedures for business networking environment.

5 REFERENCES

[1] Azevedo, A., Toscano, C., 1999, An Information System for Distributed Manufacturing Enterprises, in Enterprise Information Systems, ed. Joaquim Filipe, Kluwer Academic Publishers, 131-138

[2] Collings, N., Loeh, H., 2000, Co-Operate Project – Solution Scope, Deliverables of Project IST 12259

[3] Azevedo, A., Oliveira, R., 1999, A Scalable Approach for Order Negotiation and Planning, ICEL99 – The 4th International Symposium on Logistics in the Information Age, Florence, Italy

[4] Aparicio, M., Chiariglione, L., Mamdani, E., McCabe, F., Nicol, R., Steiner, D., Suguri, H., 1999, FIPA-Intelligent Agents from Theory to Practice, Telecom 99, Geneva

[5] O´Brien, P.D., Nicol, R.C.,1998, FIPA – towards a standard for software agents, BT Technology Journal, Vol. 16, No 3

[6] Poslad, S., Buckle, P., Hadingham, R., 2000, The FIPA-OS agent platform: Open Source for Open Standards, Proceedings of the 5th International Conference and Exhibition on the Practical Application of Intelligent Agents and Multi-Agents